Cadmium Replacements for High Strength Steel Fasteners

Anthony Eng
NSWCCD-SSES

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
MAR 2005		**00-00-2005 to 00-00-2005**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Cadmium Replacements for High Strength Steel Fasteners	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center Philadelphia,Carderock Division-Ship Systems Engineering Station,5001 South Broad Street,Philadelphia,PA,19112-1403**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
25th Replacement of Hard Chrome and Cadmium Plating Program Review Meeting, March 15-17, 2005, Greensboro, NC. Sponsored by SERDP/ESTCP.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**15**	

Points of Contact

- Anthony Eng, DSN 443- or 215-897-7937, EngAT@nswccd.navy.mil
- James Jennings, DSN 443- or 215-897-7869, JenningsJC@nswccd.navy.mil
- James Soisson, DSN 443- or 215-897-1628, SoissonJP@nswccd.navy.mil
- Fredrick Kachle, DSN 443- or 215-897-7923, KacheleFR@nswccd.navy.mil
- John Allison, DSN 443- or 215-897-1236, AllisonJ@nswccd.navy.mil

Naval Surface Warfare Center
Carderock Division
Naval Ship Systems Engineering Station
Code 622, Bldg 619
1569 Constitution Ave
Philadelphia, PA 19112-1403

Background

- Cadmium commonly used on steel fasteners
  - easy deposition, corrosion resistance, low CoF, solderable
  - probable human carcinogen
  - can cause anemia, emphysema, and bone, kidney & liver diseases
- Chromium (VI) commonly used as a post treatment on Cd
  - enhances corrosion resistance of cadmium
  - human carcinogen
  - can cause ulcers and lung cancer
- Cd & Cr impact on life cycle costs
  - satisfactory performance
  - operator exposure, environmental emissions
  - waste related processing

Objectives

- Eliminate the use of electroplated Cadmium in high strength steel fastener applications
- Reduce and/or eliminate the use of Chromium in high strength steel fastener applications

JTP Tests

- General Properties
  - appearance (visual inspection)
  - coating thickness (ASTM B487)
  - max temperature (24 hr exposure-visual inspection)

- Corrosion
  - SO_2 salt fog w/ & w/o defect (500 hr ASTM G85-A4) [fastener & panel]
  - cyclic wet/dry corrosion w/ & w/o scribe (160 cy GM9540P) [fstnr & pnl]
  - galvanic bi-metallic (GM9540P)
  - fluid w/ & w/o scribe [coupon]

- Adhesion
  - water boil (modified ASTM D3359 - A)
  - bend (ASTM B571) [pnl]
  - paint (dry & water immersion) (ASTM D3359 - B) [pnl]

JTP Tests (continued)

- Assembly
  - breakaway torque w/ & w/o corr expos (ASTM G85-A4 & GM9540P)
  - fastener COF (1/3 & 2/3 YS, 3 cycles)
  - torque tension (30, 40, 50, 60, 70, 80, 90% YS, 5 cycles)

- Longevity
  - fatigue (NASM 1312-11) @ 70±30 ksi mean stress w/ & w/o corr expos
  - stress durability (ISO 15330) @ 96 hr w/ & w/o corr expos
  - slow strain rate (ASTM F606) @ 0.001”/min w/ & w/o corr expos
  - strippability (MIL-S-5002D) [fstnr & pnl]
    - bend test after coating reapplication
    - stress durability (ISO 15330) @ 96 hr before & after ctg reapplic

Test #	Test Name	Other Samples	Coated 4”x6” plate	Uncoated Fastener Systems	Coated Fastener Systems	GM 9540 Fastener Systems	ASTM G85 A4 Fastener Systems
3.1.1	Appearance	-	-	-	10	-	-
3.1.2	Coating Thickness	-	-	-	3	-	-
3.1.3	MaximumTemp.	-	-	-	3	-	-
3.2.1 3.2.3	Unscribed Corrosion Exposure	-	6	-	20	-	-
3.2.2 3.2.4	Scribed Corrosion Exposure	-	6	-	20	-	-
3.2.5	Galvanic Bi-Metallic Corrosion	45 washers	-	-	-	-	-
3.2.6	Fluid Exposure	120 coupons	-	-	-	-	-
3.3.1	Water Boil	-	-	-	3	-	-
3.3.2	Bend Adhesion	-	3		-	-	-
3.3.3	Paint Adhesion	-	9	-	-	-	-
3.3.4	Water Immersion Paint Adhesion	-	27	-	-	-	-
3.4.1	Breakaway Torque	-	-	-	10	10	10
3.4.2 3.4.3	COF Torque Tension	-	-	-	10** 10**	-	-
3.5.1	Fatigue	-	-	5	5	5	5
3.5.2	Stress Durability	-	-	10	10	10	10
3.5.3	Slow Strain Rate	-	-	10	10	10	10
3.5.4	Strippability	-	-	-	10	-	-

JTP Status

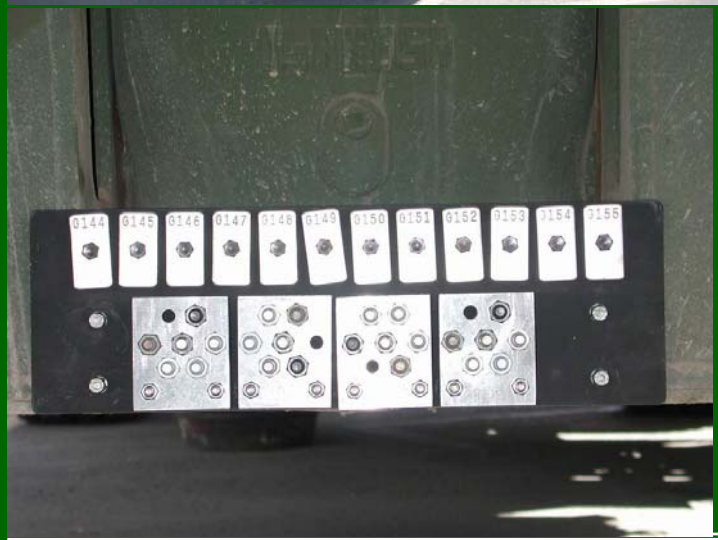
- Draft issued 17 Mar 2004 and sent to 39 technical stakeholders/contributors
- 291 comments received and adjudicated
  - Eric Brooman (AFRL)
  - Joe Osborne (Boeing)
  - Harry Archer (NSWCIHD)
  - Ralph Adler (ARL)
  - Tim Tenopir (PHD NSWC)
  - Michael Kane (AMCOM)
  - Patrick Doyle (NAWCADLKE)
- Selected Issues
  - Zn vs Cad as control
  - Grade 8 (150 ksi) vs 180 ksi or 220 ksi fasteners
  - Use of dry film lubricants
  - Mandatory and service specific tests/requirements

Preliminary Field Demo

- Fastener: 1.25” (length), 3/8” - 16 UNC grade 8, hex head cap screw
- Nuts installed/removed 5 times
- Fasteners torqued to 90%YS on 4142 plate
- 1 hr dwell, torque reapplication
- Installed on MTVR (Lejeune, NC; Kaneohe Bay, HI; Okinawa, Japan)

Candidate Coating Systems

- Zn with Cr post treatment
- Zn with proprietary non Cr treatment
  - Cd originally planned
- Zn/Al Flake in inorganic binder with friction control TC
- Zn/Al Flake with Cr in inorganic binder with friction control TC
- ZnNi per SAE AMS2417E
- ZnNi with silicate surface conversion and black UV TC


0144
0145
0146
0147
0148
0149
0150
0151
0152
0153
0154
0155


K264
K265


KB #205


OK #201


KB #100


CL#118

Torque Data

	DFT (mils)	COF	Initial Torque (ft-lb)	Unexpos BA Torque (ft-lb)	1 Yr Fld Expos BA Torque (ft-lb)	BA Torque % Change
Zn w/Cr	~0.3	0.11	46	38	60	159
Zn w/NC	~0.3	>0.08	50	41	47	113
Zn/Al	0.4-0.6	0.11	46	21	28	137
Zn/Al/Cr	0.2-0.5	0.11	46	22	28	125
ZnNi	0.3-0.5	0.08	70	62	58	94
Modified ZnNi	0.25	0.13	53	32	30	96

Slow Strain Rate Data

	DFT (mils)	Initial Unexposed UTS (ksi)	1 Yr Field Exposure UTS (ksi)	UTS % Change
Zn w/Cr	~0.3	166	164	98.4
Zn w/NC	~0.3	164	162	98.9
Zn/Al	0.4-0.6	170	169	99.3
Zn/Al/Cr	0.2-0.5	166	165	99.6
ZnNi	0.3-0.5	170	167	98.6
Mod ZnNi	0.25	170	161	94.6

Note: thread stress area based on ASTM F606, $A_s=0.7854\,[D-0.9743/n]^2$

Conclusions

- Draft JTP issued
- Draft JTP reviewed by technical stakeholders
- Draft JTP comments adjudicated
- Field exposure test on operational USMC vehicles initiated
- 1 yr field exposure samples collected (analysis ongoing)
- Based on data collected to date:
  - ZnNi and modified ZnNi coatings appear to maintain lubricity
  - Zn w/NC and Zn/Al coatings are displaying the most surface corrosion
  - Hydrogen embrittlement has not been detected wrt coating application nor during field service
- Further JTP coordination on hold until endorsement by DOD